Chapter 10 - Version 2.0
Freshwater Spawning and Rearing Habitat

This chapter examines evidence that changes to freshwater spawning and rearing (FSR) habitat have affected Columbia river spring/summer chinook salmon stocks. Ideally this analysis would be completed by comparing trends over time in abundance or productivity of these stocks and relating them to observed trends in measured habitat parameters known or thought to be associated with stock productivity. There are several reasons, however, why such an analysis is far from straightforward (c.f. Bisson et al. 1992). First, there are no conventional definitions of habitat that unequivocally guide the choice of parameters to be measured. While some parameters are obvious, habitat is a multi-dimensional feature of an animal's environment, and thus examining habitat along a single axis (e.g., temperature, percent cover) can be uninformative or even misleading. Second, the spatial and temporal scales of habitat effects are almost always poorly understood, so that it is difficult to decide where to measure habitat and its effects, and how long to wait before a response should be expected. Third, we often look for habitat effects by measuring things (such as land use patterns) that we *presume* are related to actual habitat features of importance to fish populations. For these and other reasons, it is very difficult to define a rigorous approach to testing the retrospective hypothesis that changes to FSR habitat can explain the observed trends in Columbia river spring/summer chinook stocks. Nevertheless there exists extensive information on habitat and land use conditions in the Columbia River basin, both currently and historically, and we have thus chosen to examine this information for evidence, albeit indirect, that might help to draw conclusions relevant to this hypothesis.

In this Chapter we will explore three lines of evidence:

1. What evidence is there that the habitat of chinook salmon has changed in the Columbia river basin over the past 75 years? Does this evidence allow us to specify the time period during which these changes occurred?

2. What evidence is there that the kinds of habitat changes that have occurred have led to, or would be expected to lead to, changes in chinook salmon populations in the Columbia river basin?

3. What evidence is there that contemporary spatial differences in habitat quality are associated with differences in population status indicators for Columbia river chinook stocks?

The first two of these topics provide a basis for drawing inferences about the likely influence of habitat change in the absence of direct evidence of effects. By showing that habitat changes have occurred (topic 1) and that the kinds of changes that have occurred have been associated with population-level effects (topic 2), either at local scales within the Columbia River basin or elsewhere, we can infer an influence of habitat change on Columbia River stocks. These topics have been the subject of numerous other published reports, so we will simply summarize the relevant details. While perhaps of limited importance to the primary goals of the retrospective analysis, this information may be particularly valuable to the prospective component of PATH, where we seek a rationale for quantifying the likely demographic consequences of specific habitat management actions.

The principal focus of the Chapter will be on the third topic. Here we will present new analyses of data from Columbia River stocks that substitute spatial comparisons for the preferred temporal analyses. We use an extensive data set of land use, physiography, and habitat conditions compiled for the Eastside Assessment (EA) to seek evidence of associations between these data and spatial patterns of contemporary stock indicators. We will examine four stock indicator data sets:

- an extensive compilation of stock presence/absence and a qualitative index of abundance (strong versus depressed) for the entire EA area and for several salmonine species including chinook
- run reconstructions and associated derived statistics (e.g., Ricker a,b values) for the stocks examined in Chapter 3 and for up to 12 additional stocks
- up to 12 years of chinook (and steelhead) parr density data from approximately 300 sites throughout Idaho sections of Snake River tributary streams
- PIT-tag release and recovery data from Snake River streams

Two other retrospective analyses complement the results presented in this chapter. In Chapter 4, a Level 2 analysis of temporal trends in aggregated habitat or land use variables seeks evidence for associations between habitat change and index stock productivity measures. In Chapter 9, a Level 3 analysis considers whether spawner-to-smolt productivity has changed for Snake River stocks since the completion of the four Snake River mainstem dams.

10.1 Evidence for historical changes to Columbia basin chinook habitat

There can be no doubt that profound and widespread changes have occurred to riverine habitats presently or formerly utilized by chinook salmon in the Columbia basin. There are innumerable accounts of the changes in land use that have occurred in the basin over the past 150 years (e.g., Sedell and Luchessa 1982; Bisson et al. 1992, McIntosh et al. 1995), resulting from the settlement and economic development of the area for food, fibre, and energy production. That these land use changes have affected river and stream habitats is also beyond question. The profound effects of impoundment are obvious, first through their influence on the area of accessible habitat where fish passage is eliminated, and second as a result of the flooding of alluvial valleys (Stanford and Ward 1993, ISG 1996). Similarly, the effects of forest cover removal, road construction, mining operations, and grazing on local and catchment-scale sediment dynamics are well documented (Rhodes et al. 1994). Stream channel simplification is frequently cited as a pervasive and influential effect of many historical land and stream management practices (Bisson et al. 1992), such as the removal of woody debris (Maser and Sedell 1994) and the hydrologic isolation of the stream channel from adjacent riparian areas (Sedell and Luchessa 1982). These changes have undoubtedly occurred throughout the Columbia River basin, and they have undoubtedly affected salmon populations. It is also important to recognize that modest amounts of habitat in the basin have been protected from alteration. For example, 30% of Idaho's stream kilometers inhabited by salmon and steelhead are located within designated wilderness areas or waterways classified as wild and scenic rivers (Hassemer et al. 1997). These areas can serve as spatial controls.

Although the accounts of historical habitat changes are numerous, they are often derived by inference from knowledge of historical land use practices, or from primarily anecdotal accounts of historical conditions. A recent study that rigorously documents changes in stream habitats is that of McIntosh et al. (1995). They resurveyed 120 streams in 21 river basins throughout the Pacific Northwest that had been surveyed during 1934-1945 and quantified changes in the frequency of large ($>= 20\ m^2$) and deep ($>= 1.8$ m) pools in those streams. They argued that large, deep pools are important habitat features for many fish species, including chinook salmon. They observed significant declines in both deep and large pool frequency in more than 45% of the re-surveyed streams, and significant increases in only 6% (deep) and 34% (large). More importantly, they divided the streams into "managed" and "unmanaged" watershed categories, based on the extent of human use (timber harvest, livestock grazing, agriculture, and mining) in the watershed. In the unmanaged watersheds they measured increases in large pool frequency, while in managed watersheds both large and deep pool frequencies declined.

The evidence for changes to FSR habitat in the Columbia River basin may be overwhelming, but a critical question for the retrospective analysis concerns the timing of these changes. In Chapter 9, Petrosky and Schaller show that spawner-to-smolt productivity (measured as ln(smolts/spawner)) and survival rate of aggregate Snake River chinook have not declined significantly between the 1962-1974 period and the 1975-1993 period, even though spawner abundance did decline during this period. This suggests that FSR habitat degradation cannot explain the magnitude of recent declines in adult recruitment, productivity and survival rate of Snake River chinook stocks (Schaller et al. 1996; Deriso et al. 1996). Their analysis could not be extended to earlier periods, however, because of a lack of data. Is it possible that a majority of habitat effects on these stocks may have occurred in earlier years? Relevant evidence comes from two sources: chinook salmon abundance trends from indices pre-dating the 1960s (Fulton 1968), and reconstructions of time periods of habitat change based on historical land use patterns (McIntosh et al. 1995).

Fulton (1968) summarized information on Columbia River basin chinook populations during the middle years of this century. Using commercial catch statistics and counts at the Bonneville dam he estimated a trend in recruitment of spring/summer chinook to the Columbia River from 1939-1965. These data do not include offshore commercial troll harvests, sport harvest, or returns to rivers below the Bonneville dam. Nevertheless they indicate an overall modestly increasing trend in recruitment during this period (declines during 39-45, increases 45-58, decline 59-65). These data do not indicate a broad decline in chinook abundance during the 1940s and 50s, as might have been expected if major habitat loss had affected production on a basin-wide scale. In contrast, Fulton (1968) documents substantial declines in fall chinook runs during this period.

McIntosh et al. (1995) examined various land use factors (livestock grazing, crop agriculture, and timber harvest) for trends in the intensity and extent of activity over time. While the patterns are regionally variable they noted in general that: (1) for livestock grazing the total use (sheep + cattle) peaked in the 1930s, but that the impact probably peaked later (1950s-60s) due to the replacement of sheep by cattle, the latter likely having a greater impact, particularly on riparian areas; (2) most agricultural development occurred prior to the 1960s; (3) timber harvest in Columbia river basin peaked in the mid-1960s, and more importantly harvest practices with the greatest impacts (riparian forest removal, log drives) occurred principally in the first half of this century. On the other hand they noted that road construction associated with logging was most intense during the period from the end of World War II to the late 1980s. These observations certainly suggest that important habitat-related impacts on the productivity of Columbia River chinook stocks may have occurred before the collection of spawner escapement data began, and thus will not be evident from analyses such as those presented in Chapters 3, 5, and 9. In fact the stocks which form the basis for the stock-recruitment analyses may only be those stocks which have persisted in the face of habitat loss - other stocks or sub-stocks may have already been extirpated by the 1960s. Unfortunately there are no historical data that allow examination of this critical question although a comparison of habitat quality between areas where stocks are known to have disappeared and areas where they remain (see 10.3) might shed some light on this issue.

10.2 Evidence that population effects of habitat change have, or are likely to have occurred.

The most convincing evidence that the habitat changes described above are, in part, responsible for observed declines in Columbia River spring/summer chinook stocks would come from comparisons of stock dynamics for stocks spanning a period of habitat change with coincident dynamics for stocks from unaltered watersheds. Unfortunately, as we noted earlier, such studies do not exist that span the entire period of interest. As noted in the previous section, many of the broad-scale habitat changes in the Columbia River basin probably occurred prior to the 1960s; good data on salmon stock dynamics do not extend back prior to the mid-1950s. The Chapter 9 analysis indicates that trends in spawner-to-smolt survival for the more recent period (1962-1993) do not show significant evidence of declines in productivity or survival rate for Snake River stocks (Petrosky and Schaller 1996), as might be expected if habitat changes were largely responsible for the recent declines in these populations. Thus we can conclude that habitat change has not contributed to recent (1970s to present) declines in productivity of Snake River stocks *as a whole*[1]. We are much less certain, however, about the effect habitat change may have had prior to the 1960s or on individual stocks.

On the other hand, there have been studies of the localized response of salmon populations to habitat change, both from within the Columbia River basin and elsewhere. These studies can be used to assess whether habitat change, in those areas where such change has been well-documented, is likely to have contributed to declines in salmon populations since the early years of this century. In this section we briefly review the evidence emerging from these studies.

Studies that have considered the effects of habitat alterations on salmon populations have considered a wide range of habitat components. We focus here on the three components that have figured most prominently in these studies: temperature, substrate composition, and channel morphology and in-stream cover. Because the causes of changes in each of these components can

[1] The Chapter 9 analysis used aggregate smolt abundance indices at the Snake River dams so the estimates of the spawner-to-smolt survival are for the Snake River aggregate, not for the individual index stocks.

be very different, as can their effect on salmon spawning and early rearing success, we have organized our summary by habitat component.

10.2.1 Temperature changes

As a cold-water species, chinook salmon (and other salmonines) are well-known to be vulnerable to elevated stream temperatures resulting from reduced groundwater contributions, reductions in overall discharge, on-stream ponding, and especially increased solar radiation due to reduced riparian shading (Everest et al. 1985; Armour 1991; Rhodes et al. 1994). Numerous studies have documented the elevated summer stream temperatures that result from streamside vegetation removal (e.g. Brown and Krygier 1970; Holtby 1988). Rhodes et al. (1994) concluded that stream temperatures above 15.5 C (60 F) would likely be detrimental to chinook salmon juveniles, and that temperatures above 18.9 C (66. F) would almost certainly result in reduced growth, emigration, and possibly mortality.

Studies on the John Day and Tucannon Rivers have demonstrated the influence of elevated stream temperatures on chinook salmon habitat use in the Columbia River basin. As described by Rhodes et al. (1994: p. 38-39):

> ‘Lindsey et al (1986) presented clear evidence regarding the effects of maximum water temperatures on spring chinook distribution. They found that distribution of spring chinook fingerlings after emergence in the John Day River, Oregon extends downstream from the three primary spawning areas. From the spawning areas in the North Fork, fingerlings extend their distribution downstream below the North Fork mouth. As water temperatures increase in early summer, juveniles migrate back upstream. On the North Fork, the lower limit of juvenile rearing retreated above river mile 70 in response to increased temperatures…A similar pattern of juvenile movement downstream after emergence, followed by a return movement upstream during July-August in response to increasing temperatures was observed in the Middle Fork. Temperature data from thermographs in the North Fork and Middle Forks of the John Day River allow regressions to be developed expressing the downstream boundary of distribution in relation to the water temperature at the thermograph. [For the North Fork] when the mean maximum water temperature was 73 F [22.8 C] for a two-week period at a point location…, no juveniles reared below that point; [For the Middle Fork - when mean maximum water temperature was 67 F [19 C]… no juveniles were found below this point… This study clearly shows that available rearing area decreases as water temperature increases.
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> ‘Data from Bugert et al. (1987)on the Tucannon River, in southeastern Washington can be used to infer summertime temperature limitations on spring chinook rearing distribution. In July-August, 1990, they surveyed spring chinook parr densities in lower 25 mile river section and found no parr... The mean daily temperature for all 31 days of August 1991 was 72 F; the mean maximum temperature for this same periods was 77 F. Theurer et al (1985) estimated that no spring chinook production would occur on sections of the Tucannon River where mean daily water temperature for July exceeds 68 F and the average maximum daily July water temperature exceeds 75 F. Consequently they estimated that about 24 miles of the Tucannon mainstem had been lost as usable habitat

> due to increases in summer water temperatures; they estimated that the elevation of water temperature had reduced production capacity from 2,200 to about 900 adult spring chinook salmon.'

In small headwater streams with dense riparian cover summer stream temperatures may actually be lower than those optimal for salmonine growth. In such cases, some removal of shade may actually raise temperatures to levels that enhance salmon growth and survival (Holtby 1988, Hartman and Scrivener 1990), although the population-level effects of these changes may not be straightforward to predict[2]. In large basins such as the Salmon River system, however, higher-order, downstream reaches depend on low temperature inputs from these headwaters reaches to maintain optimal summer temperatures in the much larger downstream rearing habitats. This trade-off between creating preferred thermal regimes in headwater reaches and causing excessive warming of downstream reaches has not been thoroughly investigated.

10.2.2 Sediment dynamics

The Columbia River basin, and particularly the Salmon River and its tributaries, has been the subject of numerous investigations of the impacts of land-use practices on sediment dynamics, and in turn the effects of sediment inputs on salmonine spawning and rearing success. By far the most widely studied and well-documented effect is due to the accumulation of fine material in riffle habitats. As stated by Rhodes et al. (1994: p 6)

> Studies have repeatedly documented that increases in fine sediment in streams reduce salmonid survival, production and/or carrying capacity; salmonid populations are typically negatively correlated with the amount of fine sediment in stream substrate (Iwamota et a;. 1978; USFS 1983; Alexander and Hansen 1986; Everest et al. 1987; Chapman and McLeod 1987; Rinne 1990; Hicks et al. 1991; Bjornn and Reiser 1991; Scully and Petrosky 1991; Rich et al. 1992; Rich and Petrosky 1994). The negative correlation of salmonid survival and production to fine sediment has been mainly attributed to reduced survival-to-emergence (STE) and the loss of interstitial rearing habitat in channel substrate.'

In Middle Fork Salmon River tributaries, differences in fine sediment levels in spawning habitats have been shown to be clearly related to both egg-to-parr survival (Scully and Petrosky 1991, Rich and Petrosky 1994), and to juvenile salmonid densities. In addition to the effects of fine sediments on egg and embryo survival, cobble embeddedness, a direct consequence of the accumulation of fine material in streams, has a strong influence on both fry rearing success during the summer (probably due to both loss of cover and diminished food production) and

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[2] Although increased stream temperatures in Carnation Creek did lead to earlier emergence, faster growth, and higher overwinter survival for coho salmon, Holtby (1988) suggested that these effects may have been offset by reduced ocean survival for these cohorts resulting from earlier seaward migration of smolts. The Carnation Creek case study illustrates the difficulty of predicting the population-level effects of a habitat alteration.

overwintering success of pre-smolts (due to a lack of cover). There is growing evidence that the interstitial spaces provided by clean, unembedded cobble provides critical winter habitat for a variety of salmonid and other riverine fish species (Rimmer et al. 1984; Riehle and Griffith 1993, Cunjak 1996).

Several studies have demonstrated the effects of land management practices, mostly notably grazing, agriculture, logging and road construction, on sediment delivery to stream in the South Fork and Middle Fork Salmon River (numerous references in Rhodes et al. 1994). The highly erodable soils in this area make these systems particularly susceptible to sediment inputs when the land is disturbed. Rhodes et al. (1994) concluded from their review that sediment delivery in excess of 25% over natural was very likely to lead to habitat degradation and reduced salmonid survival.

The South Fork Salmon River, where massive sediment deposition in the 1950s and 60s was followed by a logging moratorium, provides evidence that the habitat loss caused by erosion and sediment delivery can be reversed. During a 15 year period following the moratorium significant reductions in fine sediment occurred; using the STE model developed by Scully and Petrosky (1991) these reductions would suggest increases in STE by an order of magnitude (Rhodes et al. 1994). Rhodes et al (1994: p. 16) concluded that, “The case history of the South Fork Salmon River clearly indicates that salmon survival can be significantly increased in a fairly short time period, but only if the causes of degradation are arrested and reversed”

10.2.3 Channel morphology and and large woody debris (LWD)

As discussed earlier in the section on historical changes to habitat, there is good evidence that intensive land management practices have led to decreases in the volume and abundance of pool habitat in salmon-producing rivers in the Columbia River basin (McIntosh et al. 1995). Pools, especially large pools with cover, are generally thought to be important and productive rearing habitats for juvenile salmonids and holding areas for pre-spawning adults. Several comparative studies have shown that salmonid standing crops are positively related to the abundance and quality of pool habitats in a stream (e.g., Nickleson et al. 1992a, Fausch and Northcote 1992), but these studies have not included chinook salmon. Further, there is little, if any, direct evidence that documents whether declines in pool habitat quantity have been associated with declines in salmonid production. Similarly, the few studies in which attempts have been made to increase salmonid production by increasing pool habitat in apparently degraded streams have, to date, produced equivocal results (e.g., Reeves et al. 1990). In some cases the absence of the expected population response may be the results of inappropriate assumptions about which habitat factors were in fact limiting production (Nickleson et al. 1992b). In, general, while it is widely held that pool habitat loss has contributed to declines in the productive potential of Columbia basin salmon rivers, and while this is consistent with our understanding of salmonid habitat use patterns, there is no direct evidence of this effect.

Closely related to the role of pool habitats in Pacific Northwest rivers is that of large woody debris (LWD). It is clear from many studies that LWD plays a central role in shaping stream channel morphology, including the creation and maintenance of pool habitats, and in providing cover for juvenile salmonids. The removal of LWD from streams leads to reduced pool abundance (relative to other habitat types) and volume, and to less sinuous channels (e.g., Fausch and Northcote 1992). It is difficult to imagine that the nearly universal practice of removing woody debris from streams in the Pacific Northwest (Sedell and Luchessa 1982) has not affected habitat in these streams in a way that in turn affected the salmonid populations that used them. Nevertheless, direct evidence that changes to LWD in streams (removals or additions) has led to corresponding changes in salmonid populations is very limited, especially for chinook salmon.

This brief review of evidence related to the likely population-level effects of habitat alterations should, if nothing else, serve to emphasize the difficulty of arriving at firm conclusions regarding these effects. There is an abundance of literature documenting changes in physical habitat that have occurred in the Columbia River basin (Rhodes et al. 1994). As well, much is known about the specific habitat requirements of many fish species, perhaps most notably salmonids (e.g., Raleigh et al. 1984?). Nevertheless studies that actually document the effects of habitat change on demographic processes (survival, growth), let alone on ultimate population effects such as recruitment or population persistence, are few and far between. For the three habitat components discussed above, the evidence of demographic effects is relatively good for changes to substrate, moderate for thermal changes, and surprisingly weak for channel structure and LWD. It is important to stress, however, that this lack of evidence is not in itself evidence for only modest effects; rather it points to the difficulty of measuring these effects in natural systems, even where they do exist. This conclusion points to the critical importance of using the future management of Columbia basin streams and their surrounding watersheds as an opportunity to carefully design and implement management experiments that allow the effects of habitat alteration to be ascertained at the population level.

10.3 Evidence that spatial differences in habitat explain spatial population patterns.

Work on this section of Chapter 10 is in progress, and at this time we will simply describe the analyses that we are currently undertaking. We welcome comments on the relevance and suitability of these analyses as part of the retrospective analysis for habitat effects. We conclude this section with a brief discussion of how we envisage using the results of the retrospective analysis to assist development of inputs for the prospective/decision analysis.

10.3.1 Eastside Assessment

The US Forest Service recently completed a broad-scale scientific assessment of aquatic resources within the Interior Columbia Basin Ecosystem Management Project (also called the Eastside Assessment: EA). The assessment area includes the Columbia River Basin east of the crest of the Cascade Mountains (Idaho, western Montana, and small portions of Nevada, Utah, and Wyoming), and those portions of the Klamath Basin and the Great Basin in Oregon. As part of this project, an extensive database of landscape features has been developed for the entire study area, which includes all watersheds of interest to PATH except the lower Columbia region west of the Cascade divide. These data include information on geophysical, vegetation, and land management features at a sixth-order watershed scale (Table 10.1). One of the analyses completed in the EA project involved a multivariate (classification tree) analysis comparing these landscape features to the distribution of chinook (and other salmonid) stocks throughout the basin. Through consultation with biologists from throughout the assessment area, the EA team rated each sixth-order watershed according to whether a particular salmonid (e.g., stream-type chinook) was present and “strong”, present and “depressed” or absent. This analysis demonstrated a convincing relationship between management intensity (particularly as indicated by road density) and stock status. We will report in more detail on the findings of this study.

10.3.2 Index stock analysis

We have assembled run-reconstructions for several (12) additional stocks in the Salmon River (Idaho) and Grande Ronde (Oregon) basins and have nearly completed the verification of these datasets. Some of these stocks tend to have data quality problems due to shorter time series, missing age composition data, or unknown hatchery influences which affect their utility for Chapter 3-style analyses. We will be selecting a subset of these additional stocks which meet minimal data quality standards (Idaho stocks--1957-90 brood years, stream or subbasin specific age composition for at least part of the time series, separation of natural/hatchery components), and adding them to the sixteen existing index stocks for to complete a larger data set for Chapter 5-style MLE estimation of Ricker, etc. parameters.

We have also derived subjective (local biologist's opinion) habitat quality ratings for spawning & early rearing, downstream rearing, and overwintering habitat for each of these index stocks. We have compared these habitat ratings to aggregated land management data from the EA dataset described above using classification tree analysis, and found that the management cluster variable (mgclus: Table 10.1) was reasonably effective at discriminating among stocks with differing habitat ratings. This gives us some confidence that the EA variables reflect habitat conditions among the stocks. Our next step will be to combine the EA data with the stock parameters (e.g., Ricker a,b values) derived for each index stock from the MLE model and seek combinations of geophysical and land management variables that best explain among-stock differences in these parameters.

10.3.3. Idaho parr density analysis

We also intend to combine the EA data with an extensive, multi-year data set of chinook (and steelhead) parr densities from Idaho streams. This latter data set includes summer (July and August) estimates of sub-yearling chinook densities and sizes (lengths) and density by size class for juvenile rainbow/steelhead and resident salmonid species. Again using multivariate statistical methods, we will attempt to explain among-site variations in parr density or length distributions using a model that includes both habitat (or land use/geophysical) differences and common year effects as independent variables.

10.3.4 PIT tag data [Paulsen write-up on PIT tag analysis will go here]

Finally, we have assembled a larger data set of PIT tag releases and recoveries than was included in the earlier Chapter 10 version (excerpted from Achord and Sanford…) and will be using the tag recovery rates at Snake River dams as an index of survival. Again we will merge these data with our extensive habitat (EA) data set, and test the hypothesis that recovery rates tend to be higher from release sites with apparently higher-quality habitat. A preliminary analysis of these data has been submitted to the SRP for review under a separate cover (*PIT-Tag Overwintering Recovery Proportions: Preliminary Results* (Paulsen et al.); submitted in first SRP package).

10.4 Discussion - implications for Prospective Analysis

In general, these analysis will seek to test the hypothesis that differences among populations in some indicator of population status (strong-depressed-absent, Ricker a,b values, parr densities, PIT tag recovery rates) are related to differences among their source watersheds in features normally (or demonstrably) associated with habitat quality. Further, we hope to distinguish between those features which can be considered anthropogenic in nature, and thus potentially subject to management intervention, and those that are non-anthropogenic (e.g., geophysical, climatic). This distinction will be important for the prospective/decision analysis.

Our proposed approach for including habitat actions in the prospective/decision analysis is described elsewhere (Peters et al.: *Tasks for PATH Decision Analysis of Spring/Summer Chinook*; submitted to SRP in first package). We envisage using results from the retrospective analyses to define plausible changes to life-cycle survival and production capacity (i.e., Ricker a,b values) resulting from changes to habitat conditions (Figure 10.1). Some of the retrospective results can be used to directly infer something about likely changes to prospective model parameters (left side of Figure 10.1), while others may require an intermediate step to judge the likely consequence of changes to life-stage survival or production for these models. One approach we are considering is to use a Bayesian belief network model (BayVam) for anadromous salmonids developed by Lee and Rieman (in review). This model would allow us to determine the range of probable outcomes at the population level given a postulated change in survival or production capacity at a specific early life stage (more precisely a postulated change in the probability distribution of the life stage survival or production capacity).

We also expect to draw upon other information resources during our development of inputs to the decision analysis. During the late 1980s sub-basin plans were developed for the protection and restoration of Columbia River salmon stocks. These plans include extensive evaluations of the opportunities for improvements to production possible through habitat management actions on a stock-by-stock (actually reach-by-reach) basis. Another product of this sub-basin planning exercise was the development of a reach-level database of habitat quality and smolt production capacity for each sub-basin. We will draw upon these materials as well as the retrospective results as we seek to derive defensible estimates of (the distribution of) probable changes in prospective model parameters (Figure 10.1).

Appendices

None yet… I'm sure there will be some….

References

lots…

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Table 10.1 (reproduced with permission **[Danny?]** from EA report xx, Table 3.4). -- Descriptions of predictor landscape variables used in the stream inventory analysis and the analysis of fish distribution. All values expressed as percents refer to the percent area of the subwatershed.

Variable Name	Description
eru	Ecological Reporting Unit
Physiographic and Geophysical Variables	
slope	area weighted average midslope
slope2	percent of area in slope class 2 (slopes >10%, <30%)
con1	percent weakly-consolidated lithologies
con2	percent moderately-consolidated lithologies
con3	percent strongly-consolidated lithologies
sdt1	percent lithologies that produce coarse-textured weathering products
sdt2	percent lithologies that produce medium-textured weathering products
sdt3	percent lithologies that produce fine-textured weathering products
alsi1	percent felsic lithologies
alsi2	percent intermediate aluminosilicated lithologies
alsi3	percent mafic lithologies
alsi4[3]	percent carbonate lithologies
pprecip	mean annual precipitation (PRISM)
elev	mean elevation (ft)
mtemp[1]	mean annual temperature
solar[1]	mean annual solar radiation
streams[1]	length of 1:100,000 streams in 6th-code hydrologic unit (miles)
drnden	drainage density (mi/mi^2)
anadac[1]	access for anadromous fish (0=no, 1=yes)
dampass[1]	number of intervening dams
hucorder[1]	number of upstream 6th-code hydrologic units
hk	soil texture coefficient
baseero	base erosion index
ero	surface erosion hazard
bank	streambank erosion hazard
Vegetation Indices plus Ownership and Management Variables	
vmf	vegetation amelioration
vegclus	clustered vegetation types
roaddn	road density class
mgclus	management classification

[1]Variable only used in analysis of fish distribution

Figure 10.1 Framework for prospective/decision analysis: habitat